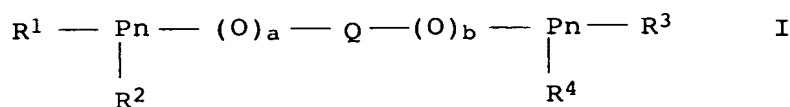


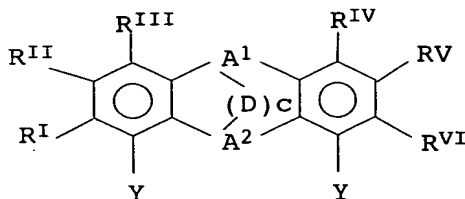
We claim:

1. A process for preparing dialdehydes and/or ethylenically unsaturated monoaldehydes by reacting at least one compound having at least two ethylenically unsaturated double bonds with carbon monoxide and hydrogen in the presence of a hydroformylation catalyst comprising at least one complex of a metal of transition group VIII with at least one ligand selected from among chelating pnictogen compounds of the formula I,



where

Q is a bridging group of the formula



where

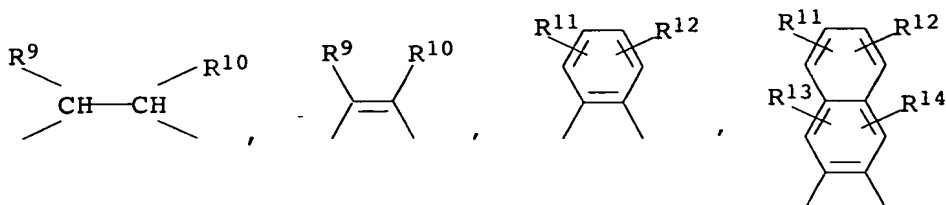
A<sup>1</sup> and A<sup>2</sup> are each, independently of one another, O, S, SiR<sup>a</sup>R<sup>b</sup>, NR<sup>c</sup> or CR<sup>d</sup>Re, where

R<sup>a</sup>, R<sup>b</sup> and R<sup>c</sup> are each, independently of one another, hydrogen, alkyl, cycloalkyl, heterocycloalkyl, aryl or hetaryl,

R<sup>d</sup> and R<sup>e</sup> are each, independently of one another, hydrogen, alkyl, cycloalkyl, heterocycloalkyl, aryl or hetaryl or the group R<sup>d</sup> together with a further group R<sup>d</sup> or the group R<sup>e</sup> together with a further group R<sup>e</sup> form an intramolecular bridging group D,

D is a divalent bridging group selected from among the groups

## 51



where

10  $R^9$  and  $R^{10}$  are each, independently of one another, hydrogen, alkyl, cycloalkyl, aryl, halogen, trifluoromethyl, carboxyl, carboxylate or cyano or are joined to one another to form a  $C_3$ - $C_4$ -alkylene bridge,

15  $R^{11}$ ,  $R^{12}$ ,  $R^{13}$  and  $R^{14}$  are each, independently of one another, hydrogen, alkyl, cycloalkyl, aryl, halogen, trifluoromethyl, COOH, carboxylate, cyano, alkoxy,  $SO_3H$ , sulfonate,  $NE^1E^2$ , alkylene- $NE^1E^2E^3X^-$ , acyl or nitro,

20  $c$  0 or 1,

$Y$  is a chemical bond,

25  $R^I$ ,  $R^{II}$ ,  $R^{III}$ ,  $R^{IV}$ ,  $R^V$  and  $R^{VI}$  are each, independently of one another, hydrogen, alkyl, cycloalkyl, heterocycloalkyl, aryl, hetaryl,  $COOR^f$ ,  $COO-M^+$ ,  $SO_3R^f$ ,  $SO_3M^+$ ,  $NE^1E^2$ ,  $NE^1E^2E^3X^-$ , alkylene- $NE^1E^2E^3X^-$ ,  $OR^f$ ,  $SR^f$ ,  $(CHR^9CH_2O)_xR^f$ ,  $(CH_2N(E^1))_xR^f$ ,  $(CH_2CH_2N(E^1))_xR^f$ , halogen, trifluoromethyl, nitro, acyl or cyano,

30

where

$R^f$ ,  $E^1$ ,  $E^2$  and  $E^3$  are identical or different radicals selected from among hydrogen, alkyl, cycloalkyl and aryl,

35

$R^9$  is hydrogen, methyl or ethyl,

$M^+$  is a cation,

40

$X^-$  is an anion, and

$x$  is an integer from 1 to 120,

or

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## 52

two adjacent radicals selected from among R<sup>I</sup>, R<sup>II</sup>, R<sup>III</sup>, R<sup>IV</sup>, R<sup>V</sup> and R<sup>VI</sup> together with two adjacent carbon atoms of the benzene ring to which they are bound for a fused ring system having 1, 2 or 3 further rings,

5

a and b are each, independently of one another, 0 or 1,

Pn is a pnicogen atom selected from among the elements phosphorus, arsenic and antimony,

10

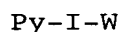
and

R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup> are each, independently of one another, hetaryl, hetaryloxy, alkyl, alkoxy, aryl, aryloxy, cycloalkyl, cycloalkoxy, heterocycloalkyl, heterocycloalkoxy or an NE<sup>1</sup>E<sup>2</sup> group, with the proviso that R<sup>1</sup> and R<sup>3</sup> are pyrrole groups bound via the nitrogen atom to the pnicogen atom Pn

15

20

or R<sup>1</sup> together with R<sup>2</sup> and/or R<sup>3</sup> together with R<sup>4</sup> form a divalent group E of the formula



25

where

Py is a pyrrole group which is bound via the pyrrole nitrogen atom to the pnicogen atom Pn,

30

I is a chemical bond or O, S, SiR<sup>a</sup>R<sup>b</sup>, NR<sup>c</sup>, substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub>-alkylene or CR<sup>h</sup>R<sup>i</sup>,

W is cycloalkyl, cycloalkoxy, aryl, aryloxy, hetaryl or hetaryloxy,

35

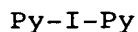
and

R<sup>h</sup> and R<sup>i</sup> are each, independently of one another, hydrogen, alkyl, cycloalkyl, heterocycloalkyl, aryl or hetaryl,

40

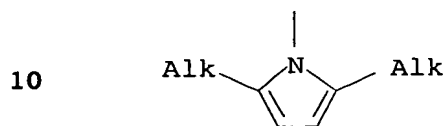
or R<sup>1</sup> together with R<sup>2</sup> and/or R<sup>3</sup> together with R<sup>4</sup> form a bispyrrole group of the formula

45

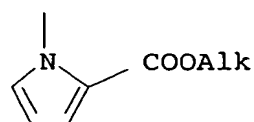


bound via the nitrogen atoms to the pnictogen atom Pn.

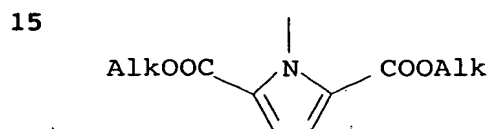
2. A process as claimed in claim 1, wherein at least one ligand of the formula I, in which the radicals  $R^1$ ,  $R^2$ ,  $R^3$  and  $R^4$  are selected independently from among groups of the formulae I.a to I.k



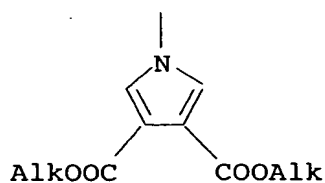
(I.a)



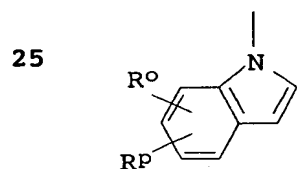
(I.b)



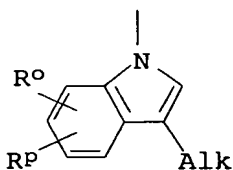
(I.c)



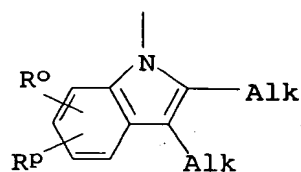
(I.d)



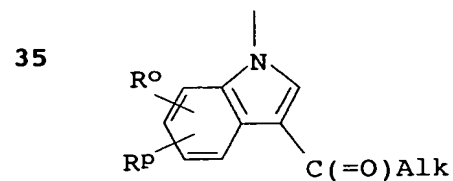
(I.e)



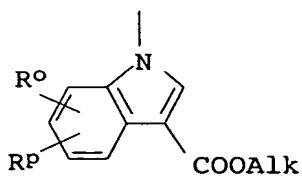
(I.f)



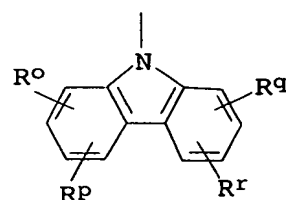
(I.g)



(I.h)



(I.i)



(I.k)

where

45 Alk is a C<sub>1</sub>-C<sub>4</sub>-alkyl group and

## 54

$R^0$ ,  $R^P$ ,  $R^Q$  and  $R^F$  are each, independently of one another, hydrogen,  $C_1$ - $C_4$ -alkyl,  $C_1$ - $C_4$ -alkoxy, acyl, halogen, trifluoromethyl,  $C_1$ - $C_4$ -alkoxycarbonyl or carboxyl, is used.

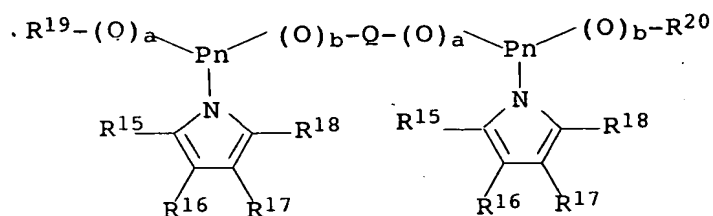
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3. A process as claimed in claim 2, wherein at least one ligand of the formula I, in which the radicals  $R^1$ ,  $R^2$ ,  $R^3$  and  $R^4$  are each, independently of one another, a 3-alkylindolyl group, preferably a 3-methylindolyl group, is used.

10

4. A process as claimed in any of the preceding claims, wherein the chelating pnictogen compound of the formula I is selected from among chelating pnictogen compounds of the formula II,

15



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(II)

25

where

$R^{15}$ ,  $R^{16}$ ,  $R^{17}$  and  $R^{18}$  are each, independently of one another, hydrogen, alkyl, cycloalkyl, heterocycloalkyl, aryl, hetaryl,  $W'COOR^k$ ,  $W'COO-M^+$ ,  $W'(SO_3)R^k$ ,  $W'(SO_3)^-M^+$ ,  $W'PO_3(R^k)(R^1)$ ,  $W'(PO_3)^{2-}(M^+)_2$ ,  $W'NE^4E^5$ ,  $W'(NE^4E^5E^6)^+X^-$ ,  $W'OR^k$ ,  $W'SR^k$ ,  $(CHR^1CH_2O)_yR^k$ ,  $(CH_2NE^4)_yR^k$ ,  $(CH_2CH_2NE^4)_yR^k$ , halogen, trifluoromethyl, nitro, acyl or cyano,

30

where

35

$W'$  is a single bond, a heteroatom or a divalent bridging group having from 1 to 20 bridge atoms,

$R^k$ ,  $E^4$ ,  $E^5$ ,  $E^6$  are identical or different radicals selected from among hydrogen, alkyl, cycloalkyl and aryl,

40

$R^1$  is hydrogen, methyl or ethyl,

$M^+$  is a cation equivalent,

45

$X^-$  is an anion equivalent and

55

y is an integer from 1 to 240,

where two adjacent radicals  $R^{15}$ ,  $R^{16}$ ,  $R^{17}$  and  $R^{18}$  together with the carbon atoms of the pyrrole ring to which they are bound may also form a fused ring system having 1, 2 or 3 further rings,

with the proviso that at least one of the radicals  $R^{15}$ ,  $R^{16}$ ,  $R^{17}$  and  $R^{18}$  is not hydrogen and  $R^{19}$  and  $R^{20}$  are not joined to one another,

$R^{19}$  and  $R^{20}$  are each, independently of one another, cycloalkyl, heterocycloalkyl, aryl or hetaryl, or  $R^{19}$  together with  $R^{15}$  or  $R^{16}$  and/or  $R^{19}$  together with  $R^{17}$  or  $R^{18}$  form a divalent group

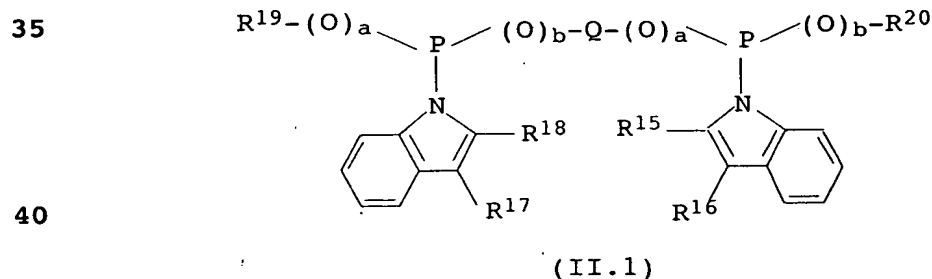
-I-W-

where

I is a chemical bond or O, S,  $SiR^aR^b$ ,  $NR^c$  or substituted or unsubstituted  $C_1$ - $C_{10}$ -alkylene, preferably  $CR^hR^i$ , where  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^h$  and  $R^i$  are each, independently of one another, hydrogen, alkyl, cycloalkyl, heterocycloalkyl, aryl or hetaryl and

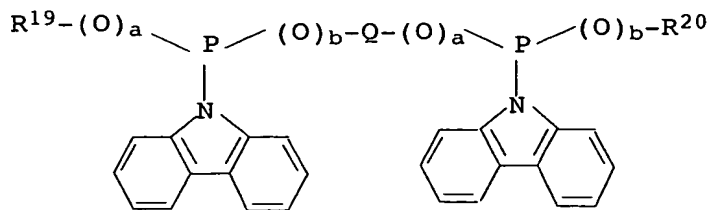
W is cycloalkyl, cycloalkoxy, aryl, aryloxy, hetaryl or hetaryloxy.

5. A process as claimed in any of the preceding claims, wherein the chelating pnictogen compound of the formula I is a chelating pnictogen compound of the formulae II.1 to II.3,

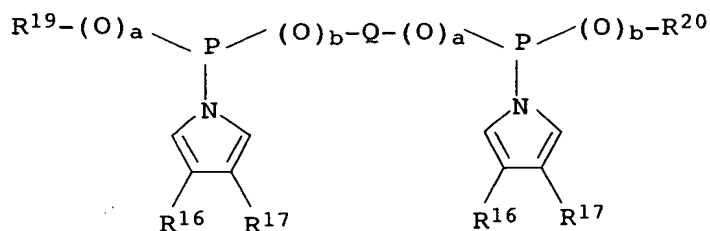


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(II.2)



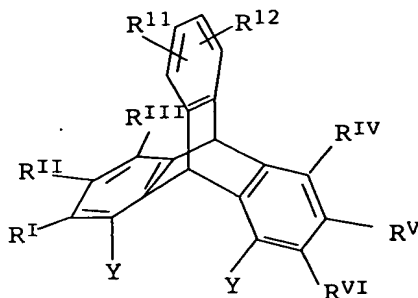
(II.3)

where

$R^{15}$ ,  $R^{16}$ ,  $R^{17}$ ,  $R^{18}$ ,  $Q$ ,  $a$  and  $b$  are as defined in claim 4, where at least one of the radicals  $R^{16}$  and  $R^{17}$  in the formula II.3 is not hydrogen,

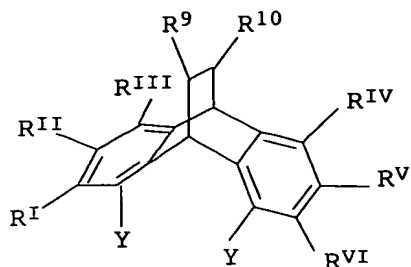
$R^{19}$  and  $R^{20}$  are each, independently of one another, cycloalkyl, heterocycloalkyl, aryl or hetaryl.

6. A process as claimed in any of claims 1 to 5, wherein the bridging group  $Q$  is a triptycenediyl group of the formula



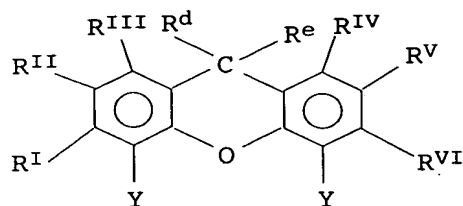
or the formula

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5  
10 where R<sup>I</sup>, R<sup>II</sup>, R<sup>III</sup>, R<sup>IV</sup>, R<sup>V</sup> and R<sup>VI</sup>, R<sup>9</sup>, R<sup>10</sup>, R<sup>11</sup> and R<sup>12</sup> are as defined in claim 1.

7. A process as claimed in any of claims 1 to 5, wherein the bridging group Q is a xanthenediyl group of the formula



15  
20 where R<sup>I</sup>, R<sup>II</sup>, R<sup>III</sup>, R<sup>IV</sup>, R<sup>V</sup> and R<sup>VI</sup> and Y are as defined in claim 1 and R<sup>d</sup> and R<sup>e</sup> are each, independently of one another, hydrogen, alkyl, cycloalkyl, heterocycloalkyl, aryl or hetaryl.

25 8. A process as claimed in any of the preceding claims, wherein a molar ratio of ligand to metal of transition group VIII of from 1:1 to 1000:1 is set in the reaction mixture.

9. A process as claimed in any of the preceding claims, wherein the reaction is carried out at from 40 to 80°C.

35 10. A process as claimed in any of the preceding claims, wherein the compound having at least two ethylenically unsaturated double bonds which is used is a  $\alpha,\omega$ -diolefin.

40 11. A process as claimed in any of the preceding claims, wherein

(i) a compound having a least two ethylenically unsaturated double bonds is subjected to the hydroformylation reaction in a reaction zone,



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(ii) an output is taken from the reaction zone and is fractionated to give a fraction enriched in unsaturated monoaldehydes and a fraction depleted in unsaturated monoaldehydes, and

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(iii) the fraction depleted in unsaturated monoaldehydes is recirculated, if appropriate after work-up, to the reaction zone.

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